REFLECTIONS ON THE AUTONOMY OF BIOLOGICAL SCIENCE

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INTRODUCTORY

IF the knowledge of facts and comprehension of principles by certain writers had been adequate, and others had freed their minds from the survivals of animism, the taxonomic position of biology in the scheme of knowledge would appear uncertain to no one. Prolonged and extensive inkshed however have surrounded this question with much unnecessary difficulty and confusion. Some claim that biology can not properly find a place among the sciences at all; others, that if our science is nothing more than physics and chemistry, it can have no right to independent existence; and finally, the vitalists postulate an absolute autonomy based on a specific principle.

BIOLOGICAL PREDICTION

Merz, Enriques,[1] and other present-day writers on the systematics of biology dwell at length on the fact that within the realm of the living, very strange and unexpected events take place. From the protozoans, human beings can hardly be inferred; the chromosomal complex, on account of the variations and surprising similarities of its constituent elements, fails to tell us whether we are dealing with sister species or with forms as remote as snails, frogs, ferns and mice. Because one crustacean is positively heliotropic, it does not follow that the next one, even if the species be identical, will respond in like manner, nor because one child in a family has blue eyes can we conclude that its parents or brothers and sisters have eyes of the same color. A dog or a

[1] Merz, John Theodore, "A History of European Thought in the Nineteenth Century"; Enriques, Federigo, "Probleme der Wissenschaft."

man may be friendly to-day and vicious to-morrow under similar external circumstances. Irregularities such as these, our informants tell us, should quench the ardor of the dullest, and to convince us still further of the inadequacy of our materials for science they point to rational mechanics, a domain free from ambush, and pervaded by an order in which only the foreseen and predictable find a place.

The juxtaposition of these two disciplines is not only unparliamentary, but unfortunate. Inasmuch as rational mechanics deals with abstractions and has only the slightest objective basis, it can have no materials comparable with the contents of any natural science. On the contrary, it is a method of thinking. Thinking is a phenomenon of consciousness; and consciousness, a biological event. If, therefore, the mechanic produces an orderly and coherent system in which one thing follows with certainty from another, this shows nothing else than that certain biological events, to wit, mental processes, are among the most reliable phenomena in nature.

The biologist readily concedes that he is not as weather-wise as the rational mechanic, but he does not concede that this is due either to the fundamental disorderliness of his section of nature, or because his colleague's oracular powers differ in origin from his own where he happens to possess them. As a whole man can not as yet be inferred from the protozoa, yet from the study of oxidation, secretion and digestion in unicellular organisms we could readily foresee the existence of these processes in higher forms. The conditions of the heliotropic response are such that an organism must be neither neutral nor alkaline to react positively, and one at variance with expectation can be made to do the expected by acidulation. Although half the children of brown-eyed parents may have blue eyes, this, instead of being a symptom of disorder, is in strict conformity with a law which enables us to say that two grandparents, one maternal, the other paternal, had this eye-color. The same

law makes it possible to predict the proportion and sex of color-blind persons in a family in which this defect is present. The change from friendliness to viciousness in dogs and men has been traced to definite chemical and structural changes so often that it could undoubtedly be foreseen if these were known. The embryologist foretells the hour of ovulation, the obstetrician the birth of a child, the entomologist the reappearance of a brood of locusts, the ornithologist of a flock of birds, and the ichthyologist of a school of fish, with the same reasonable certainty with which the celestial mechanic predicts the return of a comet. By the behavior of *Convoluta roscoffensis,* even though far from its native haunts, it is possible to tell the state of the tides. It should never be forgotten that Weismann predicted the phenomena of maturation in the germ cells.

Because the chromosomes have at present no taxonomic importance, Merz concludes that they never can have, and that biological events are therefore disorderly. It so happens that the particular facts which Merz would like to predict from these bodies are not related to what we know about them in a manner so intimate that in the present state of science prediction here would be any more reasonable than in the absence of wind to judge the weather from a bonfire. There are no reasons to doubt that if we knew accurately the chemical structure of the chromosomes, instead of merely their general composition, number, size and shape, we could tell the species, and perhaps predict their composition in related species, much as the organic chemist predicts the make-up of one compound from another. Even now, the physiological state of the cell, and in numerous instances its kind, as well as the sex of the individual from which it was taken, can be determined from the chromosomal complex.

How the rational mechanic acquired his prophetic powers can be answered by considering the development of geometry. Are we expected to believe that from the

qualities of a line, the geometrician could predict the properties of the angle between two lines, if he had yet to discover the possibility of angles? Knowing angles, he could probably tell in advance not a few of the properties of triangles, but can any one imagine, on the basis of this information alone, the relations which enable us to measure the heights of trees we have never climbed, or the distances of sun and moon? On the contrary, the history of the subject shows that the mechanist is now able to predict the motions of bodies, and the properties of configurations, not because he deals exclusively with prediction, but because he has made certain valid assumptions concerning space, and by deduction has *discovered* their consequences. He deals with controlled materials, but the trick of augury has no other secret than knowledge.

The Specifically Biological Problem

If we reject the classification of biology necessitated by a belief in the fundamental disorderliness of its phenomena, two mutually exclusive views remain to be considered. Fortunately for the biologist the discord between them is quite unnecessary, for biology may be physics and chemistry and autonomous at the same time.

Some of the most fruitful and illuminating discussions in recent years have emanated from biological chemists and physicists, and it is hard to follow the literature on these subjects without sensing the enormous possibilities with which it is freighted. It must not be supposed, however, that proof of the purely physical-chemical nature of vital processes will show that living things are in any way different than they really are. Whether analysis can subtract qualities from things certainly seems an idle question, yet we are constantly being told that the reduction of the phenomena of life to a chemical-physical basis will demonstrate that living things are, after all, not alive!

Anatomical and histological analysis of a horse is in-

capable of showing that this animal is a cow. Even if we reduce its tissues to their constituent chemical elements, and, not content with this, continue until we have shown that a horse is entirely composed of electrons, and their activities, how could this show that a horse is not a horse? If therefore resolution can detract nothing from the things analyzed, it is clear that if these are in any way unique, they will be no less so after this process than before. The only question which can be at issue is whether living things are, or are not, unique. To this only an affirmative answer is possible.

To reason with defectives is unprofitable for they have no organ with which to perceive the qualities by which we differentiate between the organic and the inorganic. If we ask ourselves how we make this distinction we naturally think of the fact that living things are machines with the power, as Loeb puts it, of automatic self-preservation and reproduction. All the wonderful processes for which in the aggregate this simple formula stands divide animals and plants sharply from matter not alive and constitute the specific basis for the autonomy of our science. This autonomy is nothing metaphysical, or absolute, but practical, like the autonomy of physics, chemistry, astronomy and geology.

HISTORICAL BACKGROUND OF THE POSTULATED ABSOLUTE AUTONOMY

In their analyses of living things, modern biologists make use of only one practical method, but they apply it from two distinct points of view, and since the significance of phenomena in general depends on the point of view, the whole meaning of the science hangs in the balance. The validity of these theoretical standpoints, therefore, should be tested as carefully as the proposed site of an observatory.

Unfortunately the issues at stake can not be properly apprehended without some knowledge of their history. To begin with Aristotle, and the few Ionians and Eleat-

ics who preceded him, however, does not give us the needed historical background, for the impression that Aristotle was a primitive man, or that science was born in Greece, is surely wrong. Scientific knowledge began with the human race.

Although the thoughts of early men are for the most part unrecorded, study of the primitive men living to-day shows conclusively that the problem of the origin and nature of life is realized by the savage. In the lore of medicine men, magicians and seers, scientific knowledge, theories and beliefs, fuse into an alloy which, despite the varied conditions of its genesis and growth, presents remarkable homogeneity. In this cultural amalgam the attempt is made to explain the difference between a dead man and a live one, by means of "a thin unsubstantial human image, in its nature a sort of vapor, film or shadow; the cause of life and thought in the individual it animates; independently possessing the personal consciousness and volition of its corporeal owner, past or present; capable of leaving the body far behind to flash swiftly from place to place; mostly impalpable and invisible, yet also manifesting physical power, and especially appearing to men waking or asleep as a phantom separate from the body of which it bears the likeness; continuing to exist and appear to men after the death of that body; able to enter into, possess and act in the bodies of other men, of animals and even of things."[2]

These conclusions, drawn from the experience of dreaming, are not much more primitive than the opinions prevalent during the middle ages and surviving in the shadows of church spires to-day. Now and again, however, revolutionary teachings arose, and the most significant of these for our immediate purposes are the doctrines of René Descartes.

In his splendid history of biological theories, Rádl[3] has traced with considerable detail the fortunes of the

[2] Tylor, Edward B., "Primitive Culture."

[3] Rádl, Emil, "Geschichte der Biologischen Theorien."

controversy set going in 1644 by the "Principes de la Philosophie" at a time when practically all men were vitalists. During the seventeenth and eighteenth centuries this contest engaged the ablest minds, yet mechanism achieved no decisive victory, but only an increase in the number of its followers, and the substitution of the original soul in vitalism by the life force of Müller, itself destined to elimination in the nineteenth century by supersession, largely by neglect, and by direct experiments on vital energetics.

Émil du Bois Reymond stands out as the champion of mechanism during this period, although the limitations of his materialism led him to classify the problem of life with six other insoluble riddles. Lotze overthrew the life force with arguments, substituted a purposeful preformation in the germ, and protected it from further harm by asserting that to inquire into its origin was unscientific. Fechner and Preyer attempted to clear the atmosphere by insisting that life is fundamental and the real problem the origin of the inorganic. Virchow contributed the idea of a mechanism superimposed upon that already known, and this in the hands of his successor Rindfleisch became a theory of atomic consciousness. In the seventies, however, ghostly voices fell upon deaf ears, for under the leadership of Darwin a seemingly satisfactory natural explanation of adaptation forced the mechanistic pendulum to its highest point.

While this period of scientific development proved fatal to naturalistic vitalism, metaphysical not only survived, but during the latter-day Darwinian decadence and reconstruction has again emerged, leaving behind some of the crudities of its forerunners, and apparently purged of ghosts. A change of names, however, does not constitute a change of nature. The ghosts, more rarefied than ever, are with us still, only to-day we call them Entelechies, Dominants, Psychoids and Élan Vital.

Analysis of Neo-Vitalism

Plate[4] finds in neo-vitalism four fundamental postulates about which discussion must necessarily center. These propositions are as follows:

I. Neither now nor in the future can the organism be explained by chemistry and physics without a remainder.

II. There is an absolute distinction between dead and living matter; in the inorganic world the law of causation holds, but in the organic causation holds together with a unique law.

III. The uniqueness expresses itself in this, that every organic process is final (teleological), that is, governed by immanent purposefulness.

IV. The cause of this finality, in so far as the vitalists are not agnostic, is (*a*) a psychical factor; (*b*) a metaphysical factor.

Postulate I

Neither now nor in the future can the organism be explained by chemistry and physics without a remainder.

Nothing could be more physical and chemical than the analysis of the whole universe into a system of electrons. When such resolution has been accomplished and every known chemical element has been shown to be a special case of corpuscular movement, the organic world and all that characterizes it will be expressible in terms of electrons if this mode of expression should appear serviceable. Would it not remain true, however, that hydrogen is hydrogen, and oxygen, oxygen? Even if these gases were proved to be configurations of essentially similar corpuscles, they would nevertheless continue to be individually different, and those so inclined would find it possible to found separate sciences of hydrogenology and of oxygenology, and these subjects would be autonomous. Does any one conclude from this that the mechanist is not fit to deal with these matters? Or that his methods are fundamentally inadequate? Yet the argu-

[4] Plate, Ludwig, "Darwinsches Selektionsprincip," 3d ed.

ment of those who would cast mechanism out of biology is identical. Resolution leaves intact uniqueness wherever found, and the declaration that this is true of the organism is a platitude.

POSTULATE II

There is an absolute distinction between dead and living matter; in the inorganic world, the law of causation holds, but in the organic, causation holds together with a unique law.

The second part of this proposition will be considered in connection with postulate III. To the first part the mechanist subscribes heartily, but adds that in his experience the distinction between hydrogen and oxygen is equally absolute.

POSTULATE III

The uniqueness expresses itself in this, that every organic process is final (teleological); that is, governed by immanent purposefulness.

In discussing postulate III, all that is needed is (*a*) to sound its logical consequences; (*b*) to inquire how it agrees with observations on individual and racial finality; and lastly, (*c*) to expose the psychology of the teleological idea itself.

(*a*) From the harmony between the organic and the inorganic, Driesch concludes that "nature is nature for a purpose." If the whole universe, however, is governed by immanent purposefulness what becomes of the distinction between the organic and the inorganic? In a purposive system the teleological nature of any particular event or group of events can not be inferred, for purposefulness can only be recognized by comparison with purposelessness. Thus general teleology denies the existence of half the materials for the inference of the very thing on which it bases itself, and with the best intentions in the world, and without in any way seeming to sense it, vitalists themselves have not only disarmed

teleology in the realm of the living, but have made the principle scientifically impossible.

(*b*) Were every organic event final or purposeful, functional adjustment, training and education would be unnecessary and impossible. Jennings[5] tells us:

> How the relations that impress us as teleological were brought about, constitutes undoubtedly a set of most difficult problems. But to keep us from despairing, we find this process taking place in the lives of individuals in a manner that can readily be studied. This is in the formation of habits. In the formation of habits, we see that the organism at first does not react in a way that impresses us as teleological, while later it does, and we can watch the process change from one condition to the other, and discover how it is causally determined. Since then a method of action that appears to us teleological is produced in an intelligible way under our very eyes, in the lifetime of the individual, there is no reason why we may not expect to find out how teleological relations have been brought about in the life of the race when we have actually made a start in the study of the physiology of racial processes. It seems clear that the apparent relation of a present process or structure to something that comes later in time is always due to the fact that this future something has in fact acted upon the organism in the past. The present condition fits the future condition only because of a certain constancy in the universe, through which the "something past" reappears again in the future.

The ability to make functional adjustments of this character is only a special case of automatic self-preservation, and is found in all organisms because those devoid of it are for this very reason eliminated and consequently remain largely unknown. Paleontology is the science that deals chiefly with these failures. How many organisms have been unable to make the necessary adjustments is attested by the great number of extinct animals and plants; how many are failing to-day is shown by every rapidly vanishing species, as well as by many experiments and special observations. Several of the mutants of de Vries have for one reason or another

[5] Jennings, Herbert S., "Diverse Ideals and Divergent Conclusions in the Study of Behavior in Lower Organisms," *American Journal Psychology,* Vol. XXI.

[6] Loeb, Jacques, "The Mechanistic Conception of Life," *Pop. Sci. Mo.,* Vol. LXXX.

proved indurable, whereas Loeb[6] has pointed out that faulty organisms must frequently arise, although we only become aware of them under exceptional conditions.

Moenkhaus found ten years ago that it is possible to fertilize the egg of each marine bony fish with sperm of practically any other marine bony fish. His embryos apparently lived only a very short time. This year I succeeded in keeping such hybrid embryos between distantly related bony fish alive for over a month. It is therefore clear that it is possible to cross practically any marine teleost with any other.

The number of teleosts at present in existence is about 10,000. If we accomplish all possible hybridization 100,000,000 different crosses will result. Of these teleosts only a very small proportion, namely, about one one-hundredth of one per cent., can live. It turned out in my experiments that the heterogeneous hybrids between bony fishes formed eyes, brains, ears, fins and pulsating hearts, blood and blood vessels, but could live only a limited time because no blood circulation was established at all—in spite of the fact that the heart beat for weeks—or that the circulation, if it was established at all, did not last long.

The possibility of hybridization goes much further than we have thus far assumed. We can cause the eggs of echinoderms to develop with the sperm of very distant forms, even mollusks and worms (Kupelwieser): but such hybridizations never lead to the formation of durable organisms.

It is therefore no exaggeration to state that the number of species existing to-day is only an infinitely small fraction of those which can and possibly occasionally do originate, but which escape our notice because they can not live and reproduce. Only that limited fraction of species can exist which possesses no coarse disharmonies in its automatic mechanism of preservation and reproduction. Disharmonies and faulty attempts in nature are the rule, the harmonically developed systems the rare exception. But since we only perceive the latter we gain the erroneous impression that the "adaptation of the parts to the plan of the whole" is a general and specific characteristic of animate nature, whereby the latter differs from inanimate nature.

If the structure and the mechanism of the atoms were known to us we should probably also get an insight into a world of wonderful harmonies and apparent adaptations of the parts to the whole. But in this case we should quickly understand that the chemical elements are only the few durable systems among a large number of possible but not durable combinations.

(*c*) Overlooking for the moment the obvious difficulties of the assumption, we can be certain that the idea of

teleology would never have entered the biologist's head were he not himself a living thing. Since this is the case, however, his interest in life exceeds all others, and he attends to the processes that make life possible only because of their resultant. Inasmuch as the latter occupies the focus of his mind, he wrongfully reasons backward from results to processes, and finding in these none that might have rendered the cherished product impossible, concludes that the processes were all along aiming at what, from his standpoint, is the end. Clearly the conclusion has only an anthropocentric basis.

Postulate IV

The cause of this finality, in so far as the vitalists are not agnostic, is (*a*) *a psychical factor;* (*b*) *a metaphysical factor.*

Since biological finality is an anthropomorphism, a discussion of the supposed teleological factors is futile. Inasmuch, however, as psycho-vitalism has its counterpart in psycho-mechanism, the fallacy common to both may be pointed out.

(*a*) To reflect mind into the cell, and so reflected to use it as an explanation of what the cell does, is the method of primitive animism. Quite apart from the fact that the existence of mind, so far, at least, has been demonstrated only in the case of certain higher animals, but not at all for the lower, or the developmental stages of the higher, as an explanation it can have no title to serious consideration since it is itself one of the elements of the automatic self-preservation which it is the aim of biology to analyze. To interpret something we do not understand in terms of something else which at present we understand even less, may give temporary comfort to some minds, but the ideals of scientific explanation call for the reverse process.

(*b*) The difficulties of Driesch's style are such that many biologists refuse to read his books. For this rea-

son I have made from one of them[7] a series of extracts to serve as illustrative material. The italics are not mine.

DRIESCH'S ENTELECHY

Entelechy or the psychoid has nothing of a "psychical" nature. (P. 138.)

We indeed are in a rather desperate condition with regard to the real analysis of the fundamental properties of morphogenetic, adaptive, and instinctive entelechies: for there *must* be a something in them that has an analogy, not to knowing and willing in general, as it may be supposed to exist in the primary faculties of psychoids, *but to the willing of specific unexperienced realities,* and to knowing the specific means of attaining them. (P. 142.)

To build up the organism as a combined body of a typical style is the task of entelechy; entelechy means the faculty of achieving a "forma essentialis"; being and becoming are here united in a most remarkable manner; time enters into the Timeless, *i. e.,* into the "idea" in the sense of Plato. (P. 149.)

There is first the entelechia morphogenetica, and after that the entelechia psychoidea and the latter may be discriminated as governing instincts and actions separately. Furthermore the different parts of the brain, such as the hemispheres and the cerebellum in vertebrates, may be said to possess their different kinds of entelechy.

In fact we may speak of an order concerning the rank or dignity of entelechies, comparable with the order of ranks or dignities in an army or administration. But all entelechies have originated from the primordial one and in *this* respect may be said to be one altogether.

Now the primordial entelechy of the egg not only creates derived entelechies, but also builds up all sorts of arrangements of a truly mechanical character; the eye, in a great part of its functioning is nothing but a camera obscura, and the skeleton obeys the laws of inorganic statics. Every part of these organic systems has been placed by entelechy where it must be placed to act well in the service of the whole, but the part itself acts like a part of a machine.

So we see finally that the different forms of harmony in the origin and function of parts that are not immediately dependent on one another, are in the last resort the consequence of entelechian acts. The entelechy that created them all was harmonious in its intensive manifoldness; the extensive structures which are produced by it are *therefore* harmonious too. In other words there are many processes in the organism which are of the statical-teleological type, which go on teleologically or purposefully on a fixed machine-like basis, but entelechy

[7] Driesch, Hans, "The Science and Philosophy of the Organism," Gifford Lectures, 1908.

has created this basis, and so statical teleology has its source in dynamical teleology.

We now see the full meaning of the statement that entelechy is an "intensive manifoldness" realizing itself extensively; in other words, we know what it means to say that a body in nature is a living organism; we have given a full descriptive definition of this concept. (Pp. 150–151.)

Any *single* spatial occurrence induced or modified by entelechy has its previous *single* correlate in a certain *single* feature of entelechy as far as it is an intensive manifoldness. (P. 154.)

Entelechy may be aroused to manifestation by a change in bodily nature, such as is effected by fertilization, or by some operation, or by some motor stimulus; on the other hand, entelechy may on its own part lead to changes in bodily nature. (P. 156.)

It is the essence of an entelechy to manifest itself in an extensive manifoldness: all the details of this extensive manifoldness depend upon the intensive manifoldness of the entelechy, but not upon different spatial "causes." (P. 157.)

Entelechy lacks all the characteristics of quantity; entelechy *is order* of relation and absolutely *nothing* else; all the quantities concerned in its manifestations in every case being due to means which are used by entelechy, or to conditions which can not be avoided. (P. 169.)

Entelechy, as far as we know, at least, is limited in its acting by many specificities of inorganic nature, among which are the specificities included under the phrase "chemical element." (P. 179.)

Entelechy is also *unable* to cause reactions between chemical compounds which never are known to react in the inorganic world. In short entelechy is altogether *unable* to create differences of intensity of any kind.

But entelechy *is* able, so far as we know from the facts concerned in restitution and adaptation, to *suspend* for as long a period as it wants any one of all the reactions which are *possible* with such compounds as are present, and which would happen without entelechy. (P. 180.)

Entelechy though not capable of enlarging the amount of diversity of composition of a given system, is capable of augmenting its diversity of distribution in a regulatory manner, and it does so by transforming a system of *equally* distributed *potentialities* into a system of *actualities* which are *unequally* distributed. (P. 192.)

Entelechy . . . is a factor in nature which acts teleologically. It is an intensive manifoldness and on account of its inherent diversities it is able to augment the amount of diversity in the inorganic world as far as distribution is concerned. It acts by suspending and setting free reactions based upon potential differences regulatively. There is nothing like it in inorganic nature. (P. 205.)

Entelechy is an elemental factor of *nature* conceived to explain a certain class of natural phenomena. (P. 206.)

You may say if you like that entelechy, when turning a mass particle, acts upon it at right angles to its path—this kind of action requiring no energy, but even thus there would be only a pseudo-obedience to the laws of real mechanics, since entelechy must be regarded here as non-energetical and as interfering with inertia at the same time. (P. 223.)

Entelechy is affected by the accomplishment of its own performance, in acting as well as in morphogenesis. (P. 228.)

In order that adaptation may happen, the fundamental state of the organism must be disturbed in its normality; this fact affects or calls forth entelechy. (P. 229.)

Entelechy is *affected* and thus called into activity by *changes of any normality* governed by it which are due to external causes and these changes *do not affect entelechy as a mere sum of changed singularities, but as changes of normality as a whole.* (P. 232.)

Entelechy is affected by and acts upon spatial causality as if it came out of an ultra-spatial dimension; *it does not act in space, but it acts into space.* (P. 235.)

Entelechy is an agent acting manifoldly without being itself manifold in space or extensity. Entelechy then is only an agent that arranges, but not an agent that possesses quantity. (P. 250.)

Entelechy is something different from matter and altogether opposed to the causality of matter. (P. 255.)

May not entelechy be called a "substance" in the most general philosophical sense of the word, that is, in the sense of a something irreducible, which remains the always unchangeable bearer of its changeable qualities. (P. 256.)

Entelechy has the power of preserving its specific intensive manifoldness in spite of being divided into two or more parts. (P. 257.)

Entelechy therefore can not possess a "seat." (P. 258.)

At present the question whether entelechy is a "substance" must remain as open as the previous question about the relation of entelechy to causality. . . . Entelechy was a kind of "quasi" causality, and now may be said to be an enduring "quasi-substance." (P. 260.)

Entelechies, though transcending the realm of the Imaginable, do *not by reason of their logical character as such* form constituents of metaphysics in the sense of something absolute and independent of a subject. (P. 320.)

Entelechy is *alien* not only to matter but *also to its own material purposes.* (P. 336.)

Mir wird vor alle Dem so dumm
Als ging mir ein Mühlrad im Kopf herum!

Conclusion

I have tried to show that biological events are orderly; that a distinct problem guarantees the autonomy of the science; that the application of physical and chemical methods has no shortcomings specifically different from those met with when applied to the inorganic, and finally that vitalism in addition to being unnecessary is absurd. The question whether the modern outburst of metaphysical biology, a movement which finds favor among philosophers and psychologists, and has no small following among zoologists and botanists, is not, despite its obvious faults, sound in motive, remains to be answered. Mechanical methods, even if applicable to vital events no less than to any others, might nevertheless possess an inherent weakness discoverable only when enlisted in biological service. The only reply possible to this question is that they are the best methods which human beings can devise, for their excellencies are grounded in our structure, their deficiencies in that of the world outside.

It has been pointed out over and over again that the explanations of science never amount to more than the enumeration of the conditions under which the events in nature take place. With ultimate explanation science does not deal, not because men of science do not want to, but because in their experience nature contains nothing ultimate. The failure, therefore, of science to give us more than it does can be held up as a fault only by those who are dissatisfied with the structure of the universe. For this feeling intellectual hygiene is the only cure.

If the limitations of scientific methods are to be found in the limitations of a limitless universe, their excellencies, as instruments for the automatic preservation of life, are to be found in ourselves, for the mechanical symbols by the aid of which natural phenomena are interpreted are the easiest for us to use. The value of these symbols depends on our power to visualize, and

visualization depends on sight. Is it without significance in this connection that the eye begins in the embryo earlier than any other receptor of special sense, or that sight, except perhaps by a few poets and musicians, is acclaimed the most priceless of all our senses?

If we lived in a world of phantasms, the value of sight would largely disappear, for, as Berkeley[8] has pointed out, it is an organ of anticipatory touch upon which depends our ability to avoid harmful collisions, and to bring about desirable ones. From the very beginning of our lives we see and deal with visible objects. Is it strange then that we should attempt to express all our experience in terms of the language which by our very structure and history is the most used and hence the most efficient medium of interpretation we possess?

Modern energetics has indeed discarded solid molecules and atoms, and has replaced these by constellations of electrons, yet even if the electrons are nothing more than electrical charges, they are believed to possess mass, and to have certain properties in common with visible things. Does not the physicist still draw pictures on the wall to make clear what he means? Is not a picture a visual symbol by the aid of which we understand a less familiar one? Escape is impossible, for mechanistic symbolism is grounded in our very nature, and for this reason its employment rises to the dignity of a moral act, for it involves neither more nor less than the application of our best capabilities to the best of all purposes—the interpretation of nature.

[8] Berkeley, George, "An Essay Towards a New Theory of Vision."